^{176}Yb(p,nγ) 1991Le28

History			
Type	Author	Citation	Literature Cutoff Date
Full Evaluation	M. S. Basunia	NDS 107, 791 (2006)	15-Sep-2005

Target: 97.04% enriched ^{176}Yb. Reaction: ^{176}Yb(p,nγ), E=8 MeV. Measured E_γ, I_γ, γγ coin. Detectors: the High Energy Resolution Array (HERA) of 21 Compton-suppressed germanium detectors. FWHM=2.32 keV at 838.5 keV.

^{176}Lu Levels

This level scheme shows γ-ray populations from an 838.5 level to both ^{176}Lu (4.00×10^{10} y, $J^\pi=7^-$) and ^{176}Lu (3.664 h, $J^\pi=1^-$), thus providing a path for production of these isomers by the s-process in stellar matter. The calculated rate of photoexcitation of ^{176}Lu (4.00×10^{10} y) to the 838.5 level as a function of temperature suggests that above 3.0×10^8 K the Lu isomers are in thermal equilibrium. The effective half-life of ^{176}Lu under such conditions is less than one year, consequently this isotope is not a reliable s-process chronometer (1991Le28).

E(level)[†]	J^π[‡]	Comments
0.0[a]	7^-	
122.9 *1*	1^-	
184.1[a] *1*	8^-	
194.4[d] *1*	1^+	
233.1[d] *1*	2^+	
235.8[b] *1*	3^-	
236.9[b] *1*	0^-	
299.3[d] *1*	3^+	
305.3[b] *1*	2^-	
338.8[c] *1*	1^+	
372.5[d] *1*	4^+	
381.3[c] *1*	2^+	
386.6[f] *1*	1^-	
388.9[a] *1*	9^-	
424.9[w] *1*	8^+	
433.0[f] *1*	2^-	
437.3[b] *1*	5^-	
450.1[c] *1*	3^+	
463.8[b] *1*	4^-	
487.6[d] *1*	5^+	
504.9[f] *1*	3^-	
533.1[c] *1*	4^+	
563.9[l] *1*	$(6)^-$	
591.7[d] *1*	6^+	
595.7[f] *1*	4^-	
635.3[q] *1*	4^+	
637.7[g] *1*	1^-	
650.2[c] *1*	5^+	
657.1[s] *1*	5^+	E(level): Adopted as a member of $K^\pi=4^+$ band: configuration $\nu7/2[514]+\pi1/2[541]$, not as a bandhead of $K^\pi=5^+$ band. See Adopted Levels for details.
658.3[j] *1*	3^-	
687.8[g] *1*	2^-	
695.7 *1*	(0 to 4)[#]	
710.0[b] *1*	6^-	

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^{176}Yb(p,nγ) 1991Le28 (continued)

^{176}Lu Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$@	Comments
715.4[f] 1	5−		
722.9[h] 1	4−		
724.7[b] 1	7−		
725.2[l] 1	(7)−		
734.0[x] 1	(7+)		
734.4[r] 1	3+		
751.7[j] 1	4−		
758.4[d] 1	7+		
763.6[g] 1	3−		
765.7[m] 1	(6)−		
772.1[c] 1	(6)+		
788.2[k] 1	4−		
792.3 1	(2)+		
796.5[&] 1	1−		
832.4[&] 1	2−		
834.8[n] 1	(5)−		
838.5[h] 1	5−	<6.9 ns	$T_{1/2}$: From τ < 10 ns, determined from timing information signals between detectors.
843.4[i] 1	3−		
848.2[f] 1	6−		
860.5[g] 1	4−		
866.1[p] 1	2+		
867.9[j] 1	5−		
870.0[o] 1	(5)−		
871.4[v] 1	(4)+		
883.5[&] 1	3−		
903.7 1	(4 to 8)[#]		
908.3[u] 1	(4)−		
921.5[k] 1	(5)−		
930.8[p] 1	3+		
938.4[c] 1	(7)+		
945.0[i] 1	4−		
957.7[&] 1	4−		
957.9[t] 1	3−		
959.2 1	(3 to 7)[#]		
960.2 1	(3)−		
973.8 1	(5)+		
985.5[y] 1	4+		
988.1[g] 1	5−		
990.0 1	(3+)		Jπ: 124.0γ to 2+ state, 617.9γ to 4+ state.
1015.1[p] 1	4+		
1019.7 1	(4+)		
1029.5[e] 1	(2)−		
1042.5[&] 1	5−		
1046.2 1	(4 to 8)[#]		
1067.4[t] 1	4−		
1100.4[e] 1	(3)−		
1104.6 1	4−[#]		
1120.2 1	(3 to 6)[#]		
1142.3 1	(0 to 4)[#]		

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^{176}Yb(p,nγ) 1991Le28 (continued)

^{176}Lu Levels (continued)

E(level)†	Jπ‡	E(level)†	Jπ‡	E(level)†	Jπ‡
1163.9 *1*	(1 to 5)#	1241.0 *1*	(4 to 8)#	1301.4 *1*	(1 to 5)#
1227.8 *1*	(1 to 5)#	1274.5 *1*	(2 to 6)#	1370.7 *1*	(2 to 6)#
1237.4 *1*	(2 to 6)#	1277.7 *1*	(4 to 8)#	1426.0 *1*	(2 to 6)#

† From a least squares fit to the γ-ray energies assuming ΔE=1 keV for all γ-ray energies.
‡ From Adopted Levels, except otherwise noted.
# Assigned in 1991Le28 based on their γ-ray decay pattern, assuming M1, E1, or E2 multipolarities. All levels have $T_{1/2}\leq 7$ ns.
@ From 1991Le28.
& Band(A): $K^\pi=0^-$. Configuration=((π 9/2(514))-(ν 9/2(924))).
a Band(B): $K^\pi=7^-$ g.s. rotational band. Configuration=((π 7/2(404))+(ν 7/2(514))).
b Band(C): $K^\pi=0^-$. Configuration=((π 7/2(404))-(ν 7/2(514))).
c Band(D): $K^\pi=1^+$. Configuration=((π 7/2(404))-(ν 9/2(624))).
d Band(E): $K^\pi=1^+$. Configuration=((π 9/2(514))-(ν 7/2(514))).
e Band(F): $K^\pi=2^-$. Configuration=((π 7/2(404))-(ν 3/2(512))).
f Band(G): $K^\pi=1^-$. Configuration=((π 5/2(402))-(ν 7/2(514))).
g Band(H): $K^\pi=1^-$. Configuration=((π 7/2(404))-(ν 5/2(512))).
h Band(I): $K^\pi=4^-$. Configuration=((π 1/2(411))+(ν 7/2(514))).
i Band(J): $K^\pi=3^-$. Configuration=((π 1/2(411))-(ν 7/2(514))).
j Band(K): $K^\pi=3^-$. Configuration=((π 7/2(404))-(ν 1/2(510))).
k Band(L): $K^\pi=4^-$. Configuration=((π 7/2(404))+(ν 1/2(510))).
l Band(M): $K^\pi=6^-$. Configuration=((π 5/2(402))+(ν 7/2(514))).
m Band(N): $K^\pi=6^-$. Configuration=((π 7/2(404))+(ν 5/2(512))).
n Band(O): $K^\pi=5^-$. Configuration=((π 7/2(404))+(ν 3/2(512))).
o Band(P): $K^\pi=5^-$. γ-vibrational band.
p Band(Q): $K^\pi=2^+$. Configuration=((π 5/2(402))-(ν 9/2(624))).
q Band(R): $K^\pi=4^+$. Configuration=((π 1/2(541))+(ν 7/2(514))).
r Band(S): $K^\pi=3^+$. Configuration=((π 1/2(541))-(ν 7/2(514))).
s Band(T): $K^\pi=5^+$. Configuration=((π 9/2(514))+(ν 1/2(510))).
t Band(U): $K^\pi=3^-$. Configuration=((π 7/2(404))-(ν 1/2(521))).
u Band(V): $K^\pi=4^-$. Configuration=((π 7/2(404))+(ν 1/2(521))).
v Band(W): $K^\pi=4^+$. Configuration=((π 9/2(514))-(ν 1/2(510))).
w Band(X): $K^\pi=8^+$. Configuration=((π 7/2(404))+(ν 9/2(624))).
x Band(Y): $K^\pi=7^+$. Configuration=((π 5/2(402))+(ν 9/2(624))).
y Band(Z): $K^\pi=4^+$. Configuration=((π 1/2(411))-(ν 9/2(624))).

γ(^{176}Lu)

E_γ†	E_i(level)	J^π_i	E_f	J^π_f	E_γ†	E_i(level)	J^π_i	E_f	J^π_f
21.9	657.1	5^+	635.3	4^+	69.5	305.3	2^-	235.8	3^-
38.7	233.1	2^+	194.4	1^+	71.5	194.4	1^+	122.9	1^-
43.3	635.3	4^+	591.7	6^+	71.7	504.9	3^-	433.0	2^-
46.4	433.0	2^-	386.6	1^-	73.1	372.5	4^+	299.3	3^+
64.5	437.3	5^-	372.5	4^+	75.7	763.6	3^-	687.8	2^-
64.6	722.9	4^-	658.3	3^-	77.3	463.8	4^-	386.6	1^-
64.8	903.7	(4 to 8)	838.5	5^-	77.3	734.4	3^+	657.1	5^+
66.2	299.3	3^+	233.1	2^+	77.6	450.1	3^+	372.5	4^+

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^{176}Yb(p,nγ) 1991Le28 (continued)

γ(^{176}Lu) (continued)

E_γ †	E_i(level)	J_i^π	E_f	J_f^π	E_γ †	E_i(level)	J_i^π	E_f	J_f^π
81.3[c]	386.6	1^-	305.3	2^-	192.2	386.6	1^-	194.4	1^+
81.9	381.3	2^+	299.3	3^+	194.6	658.3	3^-	463.8	4^-
90.9	595.7	4^-	504.9	3^-	197.2	433.0	2^-	235.8	3^-
91.1	959.2	(3 to 7)	867.9	5^-	200.0	433.0	2^-	233.1	2^+
91.6	843.4	3^-	751.7	4^-	[x]201.2‡				
93.3	751.7	4^-	658.3	3^-	201.5	437.3	5^-	235.8	3^-
99.3	734.4	3^+	635.3	4^+	201.7	765.7	$(6)^-$	563.9	$(6)^-$
104.1	591.7	6^+	487.6	5^+	203.5&	838.5	5^-	635.3	4^+
104.9	299.3	3^+	194.4	1^+	204.7	388.9	9^-	184.1	8^-
105.7	338.8	1^+	233.1	2^+	204.7	637.7	1^-	433.0	2^-
109.5	1067.4	4^-	957.9	3^-	205.5	504.9	3^-	299.3	3^+
112.8	1142.3	(0 to 4)	1029.5	$(2)^-$	207.7	1046.2	(4 to 8)	838.5	5^-
112.9	235.8	3^-	122.9	1^-	208.3	960.2	$(3)^-$	751.7	4^-
114.0	236.9	0^-	122.9	1^-	214.4	871.4	$(4)^+$	657.1	5^+
115.1	487.6	5^+	372.5	4^+	216[c]	338.8	1^+	122.9	1^-
115.6#	838.5	5^-	722.9	4^-	217.0	450.1	3^+	233.1	2^+
116.1	867.9	5^-	751.7	4^-	218.0	722.9	4^-	504.9	3^-
118.8	1104.6	4^-	985.5	4^+	219.2	591.7	6^+	372.5	4^+
119.7	715.4	5^-	595.7	4^-	222.1	945.0	4^-	722.9	4^-
120.3	843.4	3^-	722.9	4^-	225.3	658.3	3^-	433.0	2^-
124.0	990.0	(3^+)	866.1	2^+	227.9	463.8	4^-	235.8	3^-
127.6	988.1	5^-	860.5	4^-	233.7	533.1	4^+	299.3	3^+
129.9	788.2	4^-	658.3	3^-	236.1	871.4	$(4)^+$	635.3	4^+
132.8	848.2	6^-	715.4	5^-	238.7	433.0	2^-	194.4	1^+
133.3	921.5	$(5)^-$	788.2	4^-	239.4	973.8	$(5)^+$	734.4	3^+
133.7	433.0	2^-	299.3	3^+	240.8	424.9	8^+	184.1	8^-
137.2	871.4	$(4)^+$	734.4	3^+	246.2	710.0	6^-	463.8	4^-
139.4	372.5	4^+	233.1	2^+	247.0	751.7	4^-	504.9	3^-
144.4	338.8	1^+	194.4	1^+	247.7	843.4	3^-	595.7	4^-
144.4	1104.6	4^-	960.2	$(3)^-$	251.2	637.7	1^-	386.6	1^-
147.4	635.3	4^+	487.6	5^+	251.4	985.5	4^+	734.4	3^+
148.2	381.3	2^+	233.1	2^+	253.9	635.3	4^+	381.3	2^+
150.7	450.1	3^+	299.3	3^+	254.8	687.8	2^-	433.0	2^-
150.8	386.6	1^-	235.8	3^-	258.8	763.6	3^-	504.9	3^-
153.3	386.6	1^-	233.1	2^+	262.5	635.3	4^+	372.5	4^+
153.3	658.3	3^-	504.9	3^-	262.7	695.7	(0 to 4)	433.0	2^-
156.4	908.3	$(4)^-$	751.7	4^-	263.7	386.6	1^-	122.9	1^-
158.5	463.8	4^-	305.3	2^-	264.4	921.5	$(5)^-$	657.1	5^+
158.5	595.7	4^-	437.3	5^-	270.0	957.9	3^-	687.8	2^-
160.6	533.1	4^+	372.5	4^+	270.7	758.4	7^+	487.6	5^+
161.2	725.2	$(7)^-$	563.9	$(6)^-$	270.9	834.8	$(5)^-$	563.9	$(6)^-$
167.9	763.6	3^-	595.7	4^-	271.7	504.9	3^-	233.1	2^+
169.1	957.9	3^-	788.2	4^-	271.7	658.3	3^-	386.6	1^-
169.7	657.1	5^+	487.6	5^+	272.8	710.0	6^-	437.3	5^-
171.9	960.2	$(3)^-$	788.2	4^-	274.6[a]	838.5	5^-	563.9	$(6)^-$
181.2@	838.5	5^-	657.1	5^+	277.7	650.2	5^+	372.5	4^+
181.3	1019.7	(4^+)	838.5	5^-	284.4	657.1	5^+	372.5	4^+
182.4	305.3	2^-	122.9	1^-	284.4	772.1	$(6)^+$	487.6	5^+
182.9	687.8	2^-	504.9	3^-	285.6[c]	1019.7	(4^+)	734.4	3^+
184.1	184.1	8^-	0.0	7^-	287.4	724.7	7^-	437.3	5^-
184.9	635.3	4^+	450.1	3^+	292.4	1237.4	(2 to 6)	945.0	4^-
185.0	843.4	3^-	658.3	3^-	299.4	957.9	3^-	658.3	3^-
185.3	908.3	$(4)^-$	722.9	4^-	301.7	960.2	$(3)^-$	658.3	3^-
186.9	381.3	2^+	194.4	1^+	303.8	1067.4	4^-	763.6	3^-
188.3	487.6	5^+	299.3	3^+	306.1	870.0	$(5)^-$	563.9	$(6)^-$

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^{176}Yb(p,nγ) 1991Le28 (continued)

γ(^{176}Lu) (continued)

E_γ †	E_i(level)	J_i^π	E_f	J_f^π	E_γ †	E_i(level)	J_i^π	E_f	J_f^π
309.1	734.0	(7^+)	424.9	8^+	493.5	1227.8	(1 to 5)	734.4	3^+
310.0	433.0	2^-	122.9	1^-	520.4	957.7	4^-	437.3	5^-
315.5	973.8	$(5)^+$	658.3	3^-	527.2	960.2	$(3)^-$	433.0	2^-
316.3	973.8	$(5)^+$	657.1	5^+	527.3	866.1	2^+	338.8	1^+
320.7	1163.9	(1 to 5)	843.4	3^-	527.5	1015.1	4^+	487.6	5^+
327.1[c]	985.5	4^+	658.3	3^-	549.0	930.8	3^+	381.3	2^+
328.4	985.5	4^+	657.1	5^+	558.2	930.8	3^+	372.5	4^+
330.5	763.6	3^-	433.0	2^-	562.6[c]	1067.4	4^-	504.9	3^-
335.7	635.3	4^+	299.3	3^+	563.9	563.9	$(6)^-$	0.0	7^-
338.5	973.8	$(5)^+$	635.3	4^+	565.2	1015.1	4^+	450.1	3^+
346.6	938.4	$(7)^+$	591.7	6^+	566.8	866.1	2^+	299.3	3^+
350.6	985.5	4^+	635.3	4^+	567.0	1301.4	(1 to 5)	734.4	3^+
355.7	860.5	4^-	504.9	3^-	578.2	883.5	3^-	305.3	2^-
357.5	921.5	$(5)^-$	563.9	$(6)^-$	578.4	1042.5	5^-	463.8	4^-
359.0	658.3	3^-	299.3	3^+	578.6	960.2	$(3)^-$	381.3	2^+
359.9	595.7	4^-	235.8	3^-	587.1	1120.2	(3 to 6)	533.1	4^+
362.6	1019.7	(4^+)	657.1	5^+	596.5	1029.5	$(2)^-$	433.0	2^-
368.6	832.4	2^-	463.8	4^-	596.6	832.4	2^-	235.8	3^-
379.8	563.9	$(6)^-$	184.1	8^-	597.9	792.3	$(2)^+$	194.4	1^+
381.9	504.9	3^-	122.9	1^-	617.9[c]	990.0	(3^+)	372.5	4^+
391.8	1029.5	$(2)^-$	637.7	1^-	624.8	860.5	4^-	235.8	3^-
392.5	988.1	5^-	595.7	4^-	631.4[c]	930.8	3^+	299.3	3^+
397.7[c]	930.8	3^+	533.1	4^+	633.2	866.1	2^+	233.1	2^+
402.5	1241.0	(4 to 8)	838.5	5^-	642.8	1029.5	$(2)^-$	386.6	1^-
410.7	843.4	3^-	433.0	2^-	642.9[c]	1015.1	4^+	372.5	4^+
410.8	848.2	6^-	437.3	5^-	660.8	960.2	$(3)^-$	299.3	3^+
419.5	883.5	3^-	463.8	4^-	667.4	1100.4	$(3)^-$	433.0	2^-
422.7	658.3	3^-	235.8	3^-	671.1	866.1	2^+	194.4	1^+
423.1	860.5	4^-	437.3	5^-	690.0[c]	990.0	(3^+)	299.3	3^+
424.9	424.9	8^+	0.0	7^-	690.7	1029.5	$(2)^-$	338.8	1^+
425.3	658.3	3^-	233.1	2^+	697.6	930.8	3^+	233.1	2^+
425.9[c]	930.8	3^+	504.9	3^-	709.5	832.4	2^-	122.9	1^-
433.1	866.1	2^+	433.0	2^-	722.0	957.7	4^-	235.8	3^-
439.2	1277.7	(4 to 8)	838.5	5^-	722.4	957.9	3^-	235.8	3^-
440.3	1426.0	(2 to 6)	985.5	4^+	724.2	1029.5	$(2)^-$	305.3	2^-
452.0	687.8	2^-	235.8	3^-	727.1	960.2	$(3)^-$	233.1	2^+
453[c]	957.9	3^-	504.9	3^-	727.7	1100.4	$(3)^-$	372.5	4^+
470.2	1120.2	(3 to 6)	650.2	5^+	735.5	1370.7	(2 to 6)	635.3	4^+
479.3	866.1	2^+	386.6	1^-	736.4	930.8	3^+	194.4	1^+
480.7	930.8	3^+	450.1	3^+	838.5[b]	838.5	5^-	0.0	7^-
485.0	866.1	2^+	381.3	2^+	902.0	1274.5	(2 to 6)	372.5	4^+
491.5	796.5	1^-	305.3	2^-					

† Uncertainties are about 0.5 keV, private communication from 1991Le28.
‡ 1991Le28 placed this γ ray between the 687.8 (2^-) and the 487.6 (5^+) levels. This placement would require an E3 multipolarity for this transition.
# Iγ=3.1 *5*.
@ Iγ=4.9 *4*.
& Iγ=7.9 *5*.
[a] Iγ=13.9 *8*.
[b] Iγ=70 *3*.

Continued on next page (footnotes at end of table)

^{176}Yb(p,nγ) 1991Le28 (continued)

$\gamma(^{176}Lu)$ (continued)

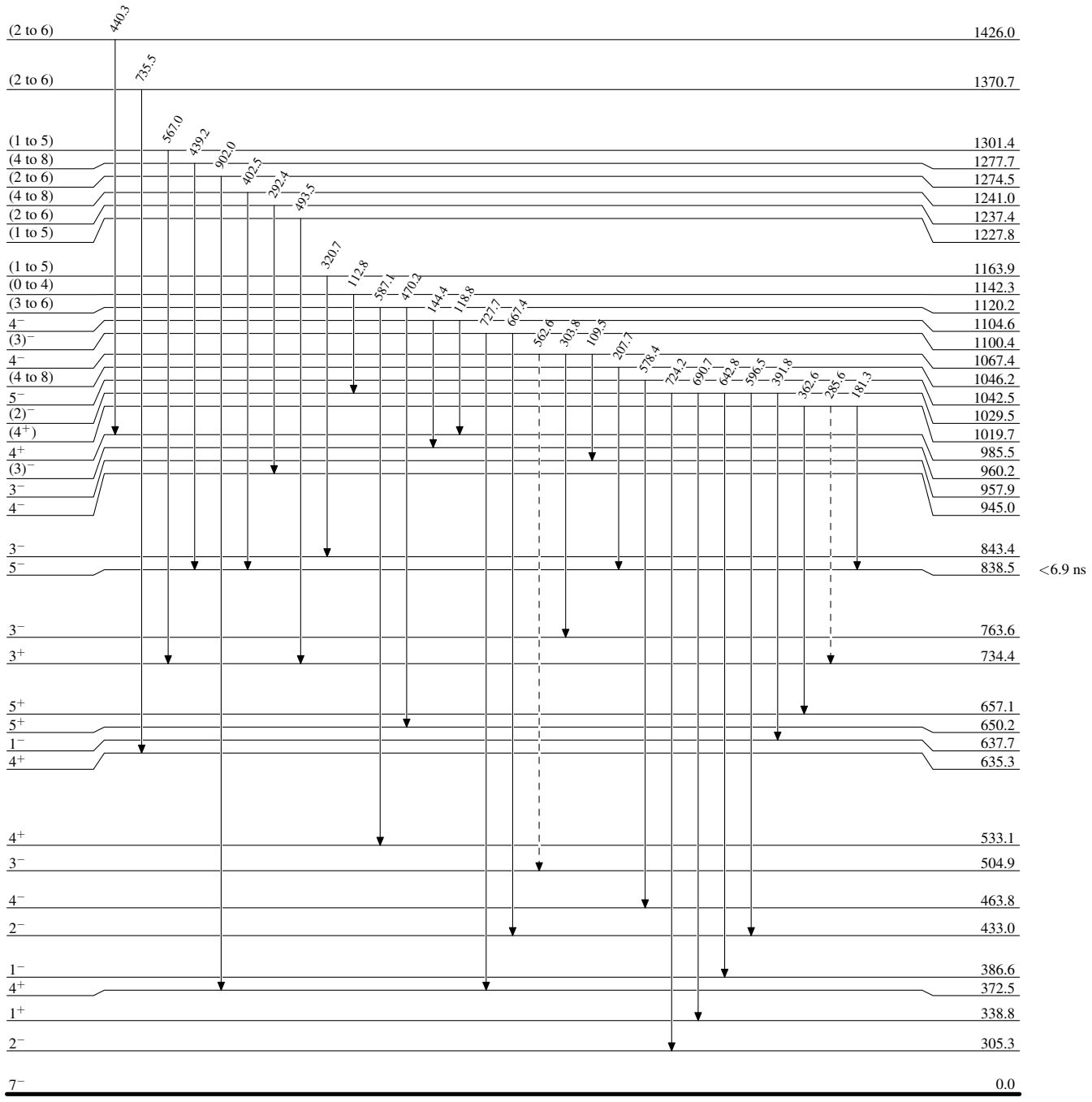
[c] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

^{176}Yb(p,nγ) 1991Le28

Legend

γ Decay (Uncertain)

Level Scheme



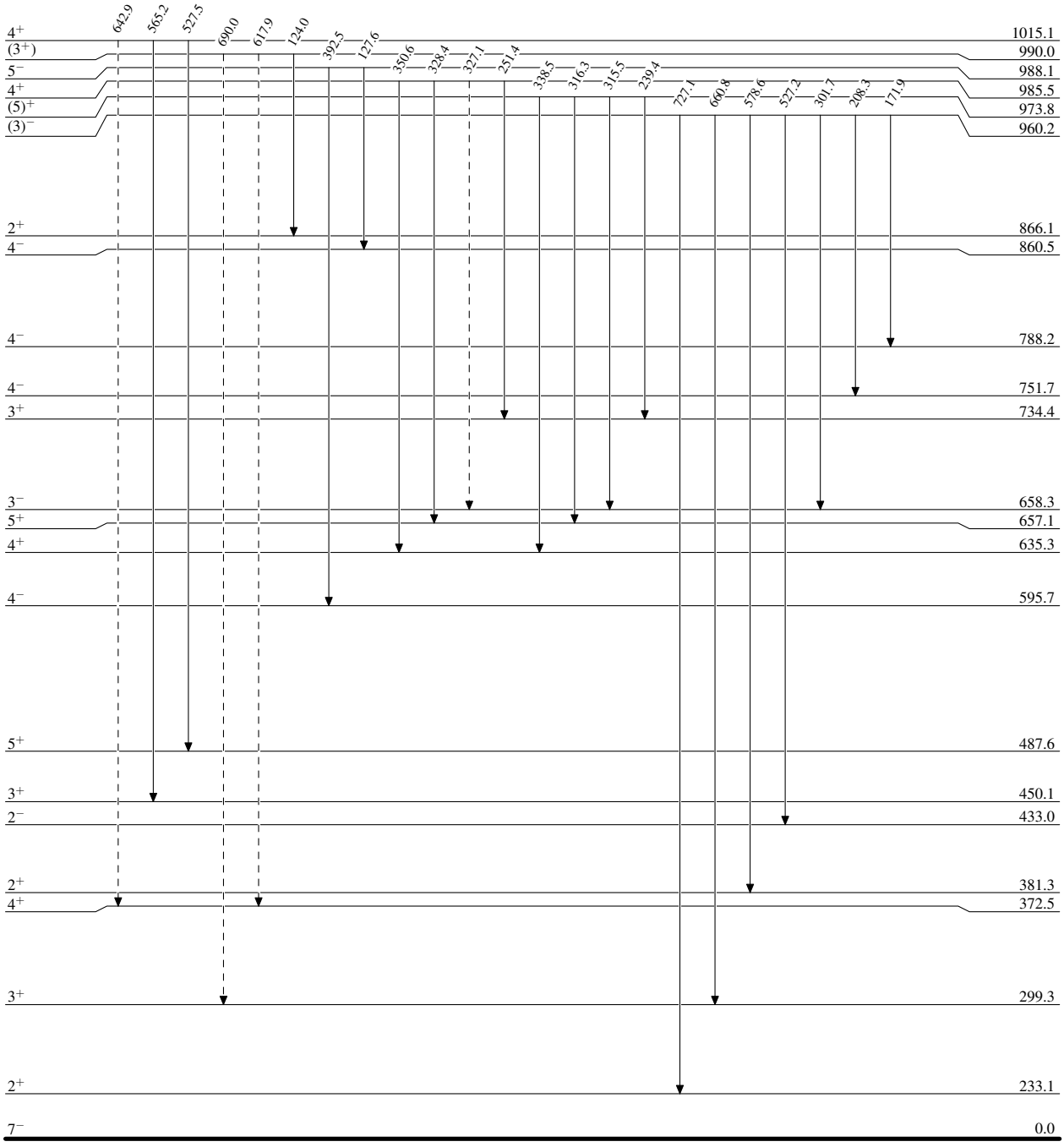
$^{176}_{71}Lu_{105}$

Legend

^{176}Yb(p,nγ) 1991Le28

Level Scheme (continued)

– – – – – – ► γ Decay (Uncertain)



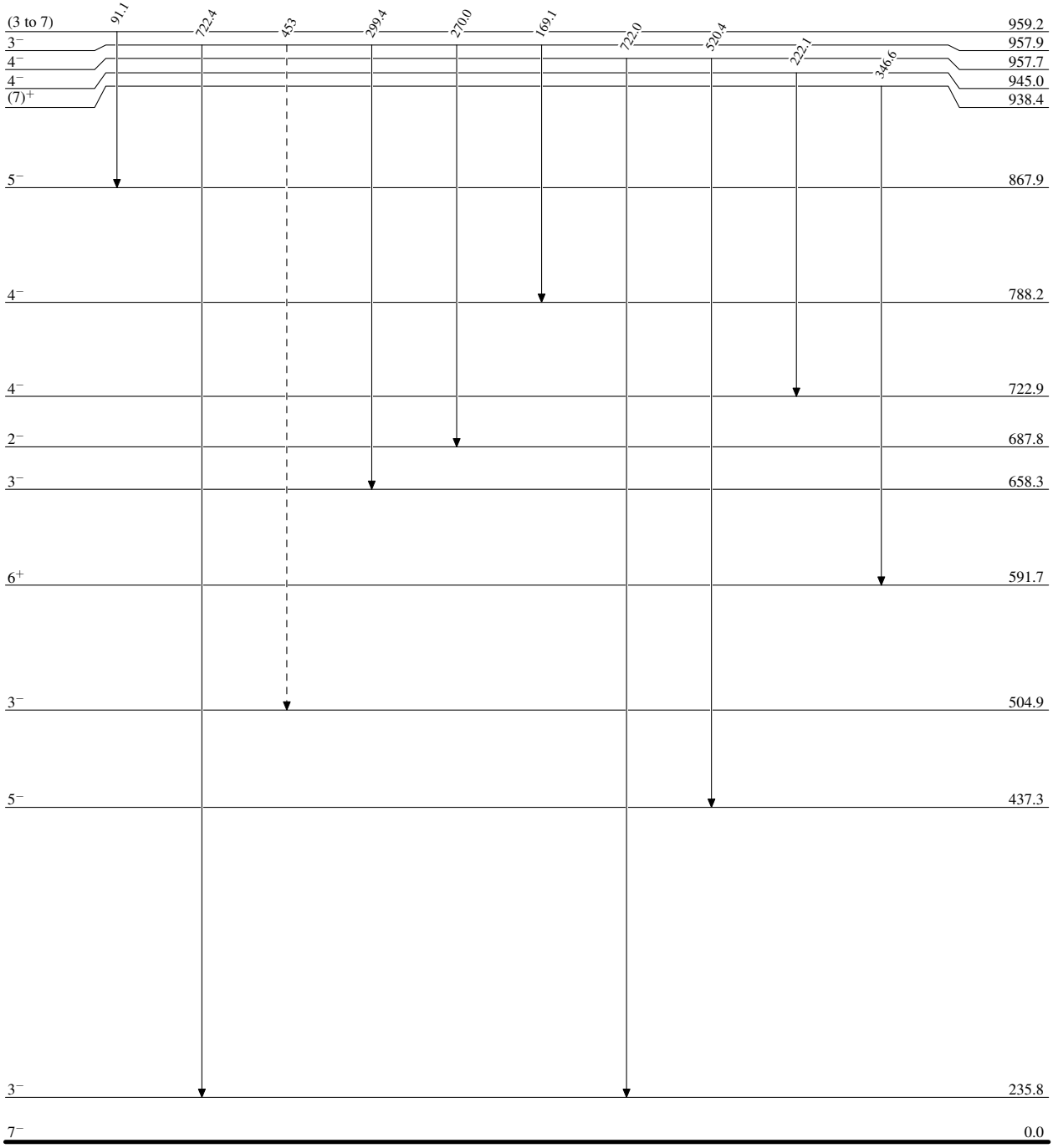
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

Legend

Level Scheme (continued)

- - - - - - ► γ Decay (Uncertain)



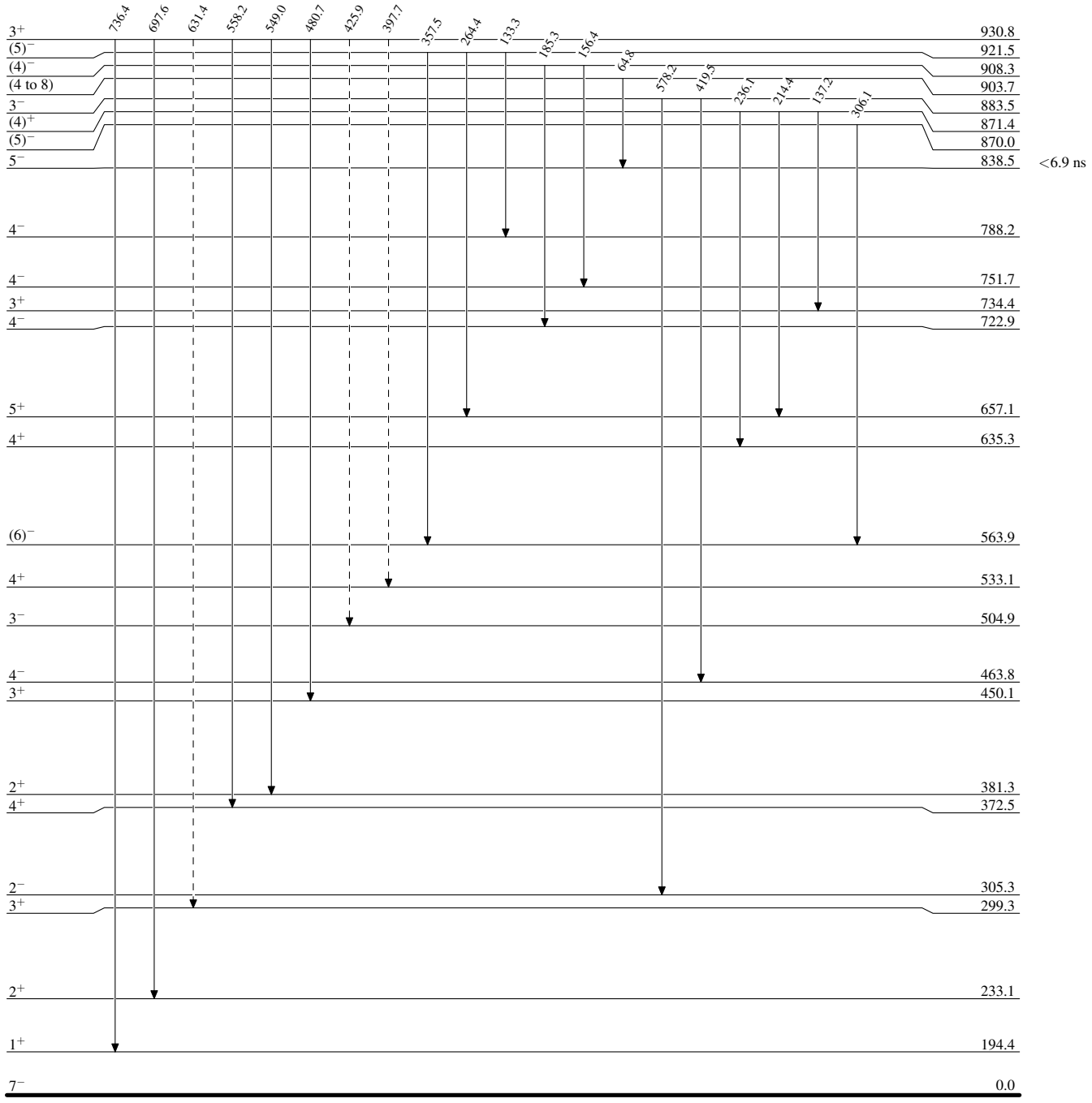
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

Legend

γ Decay (Uncertain)

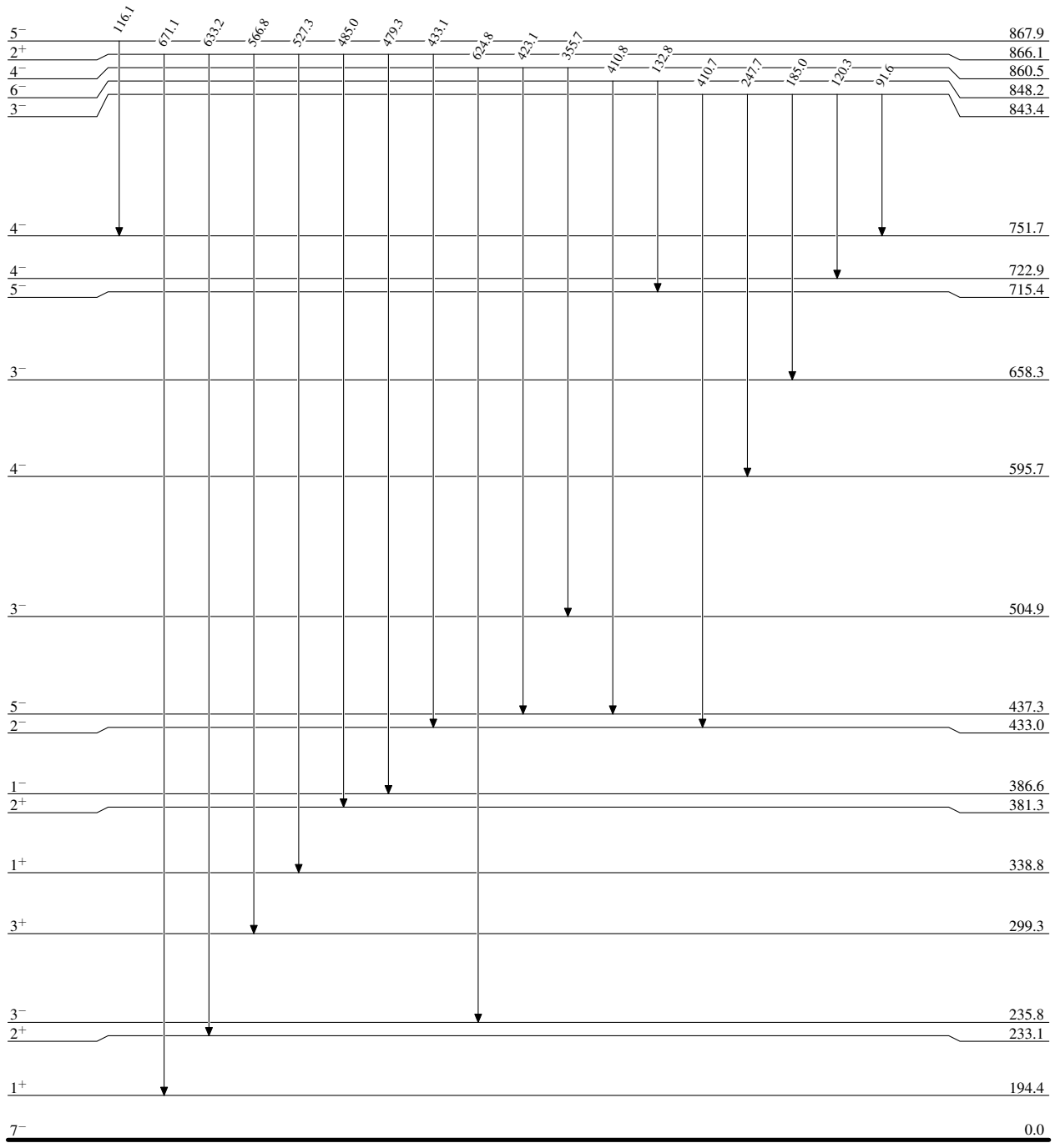
Level Scheme (continued)



$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

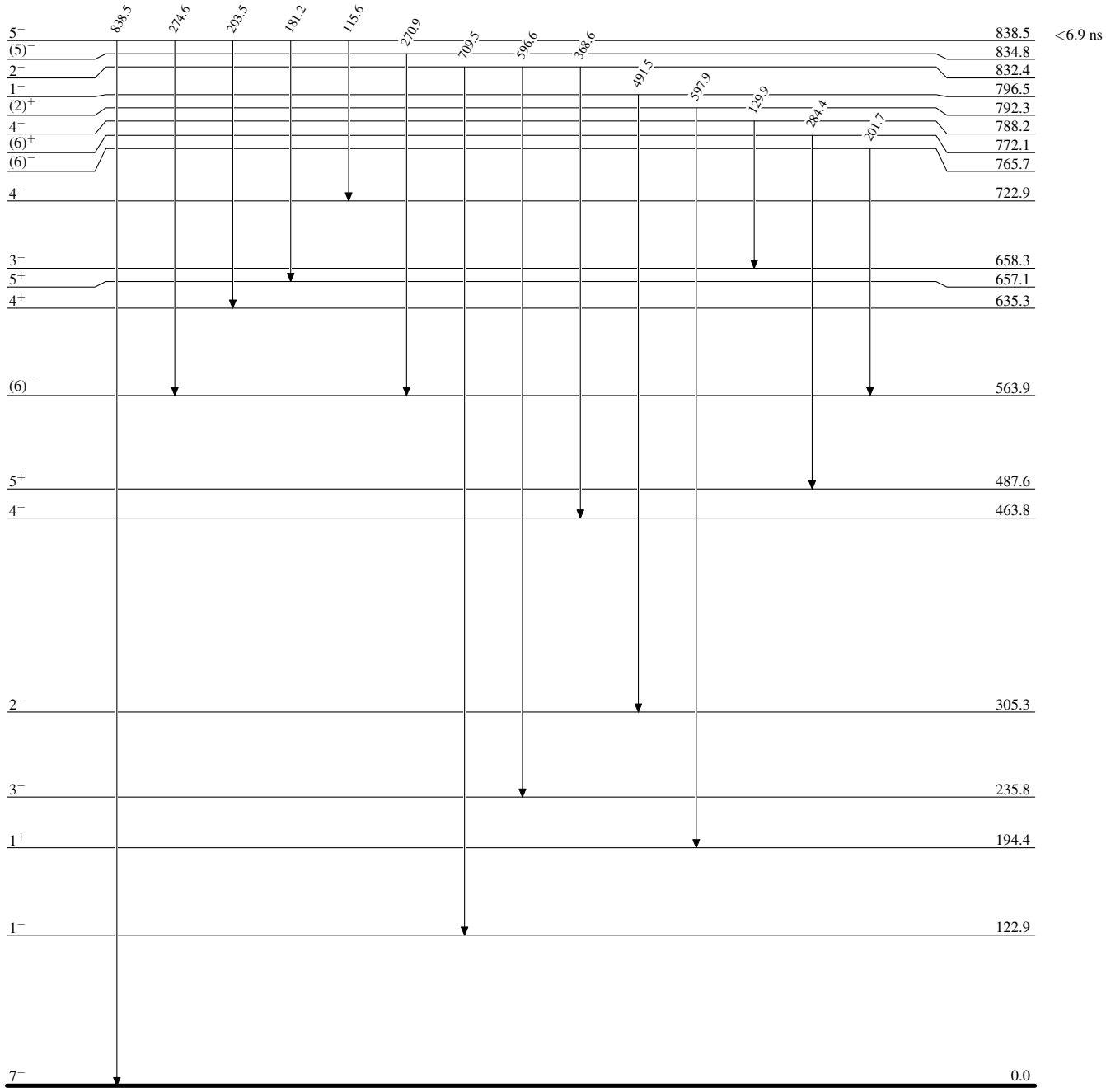
Level Scheme (continued)



$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

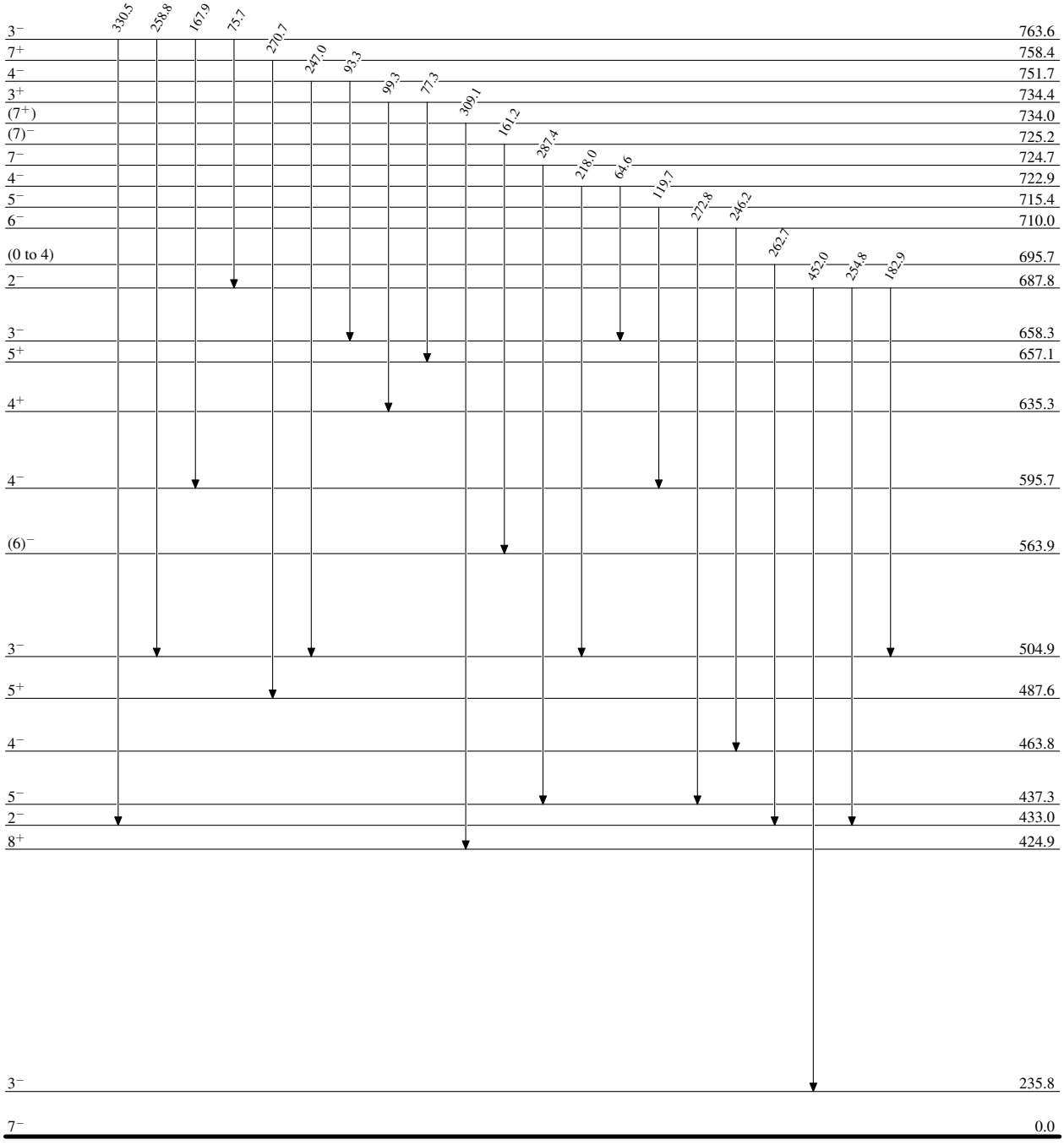
Level Scheme (continued)



$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

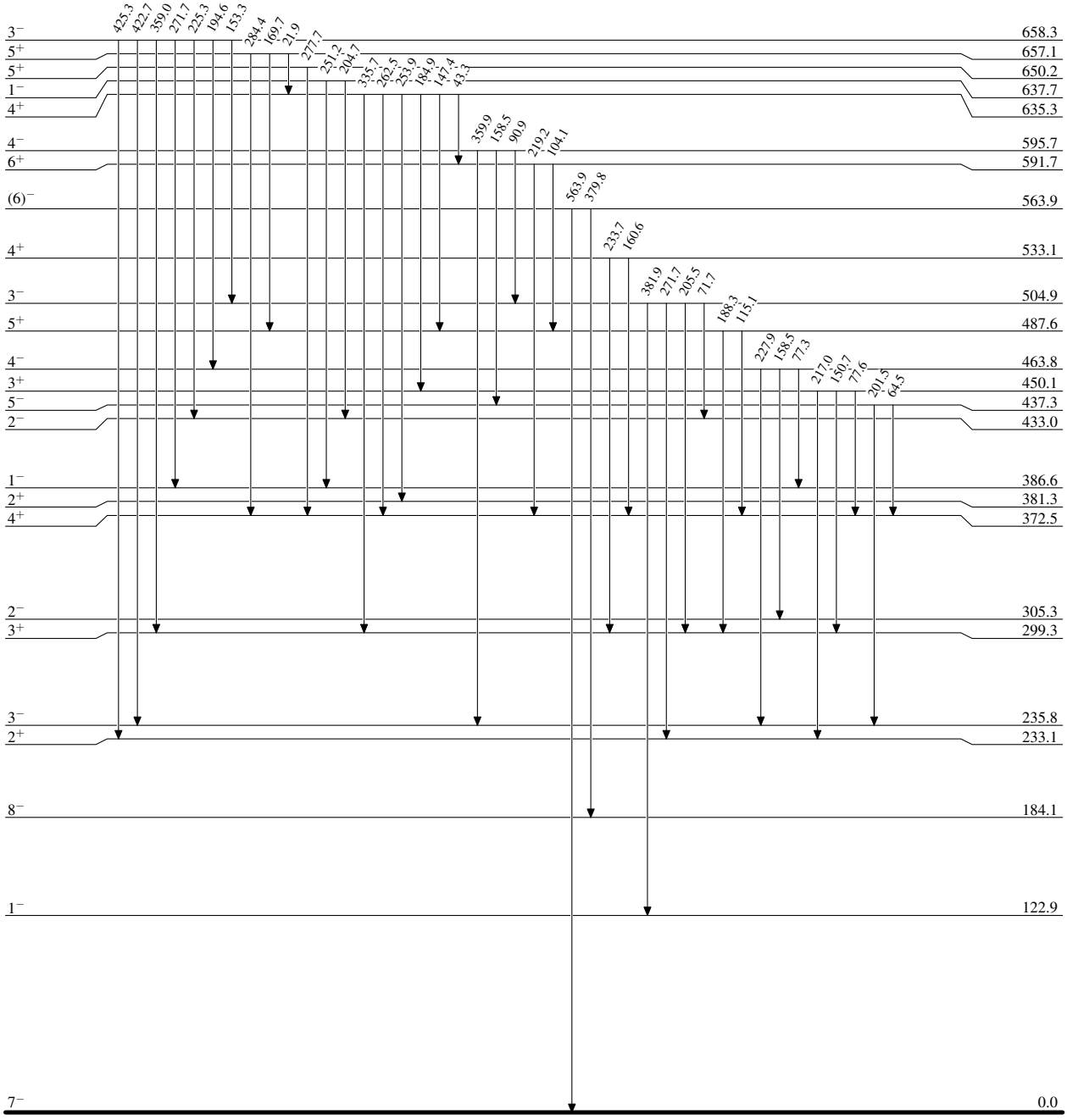
Level Scheme (continued)



$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28

Level Scheme (continued)



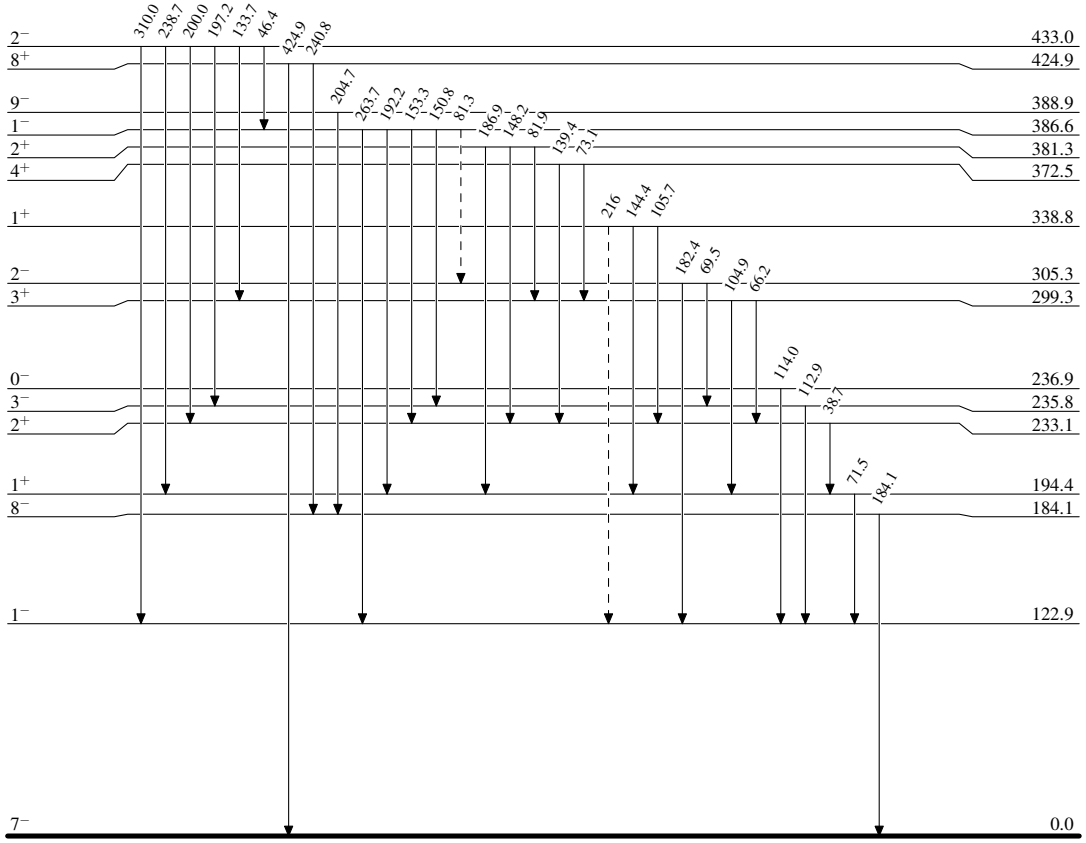
$^{176}_{71}Lu_{105}$

Legend

^{176}Yb(p,nγ) 1991Le28

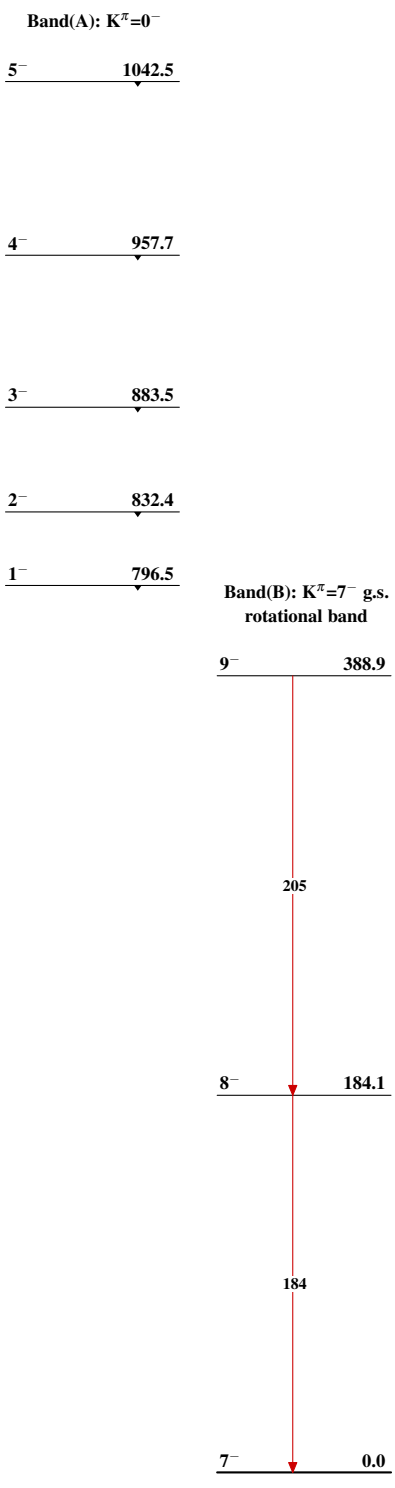
Level Scheme (continued)

- - - - - - ► γ Decay (Uncertain)



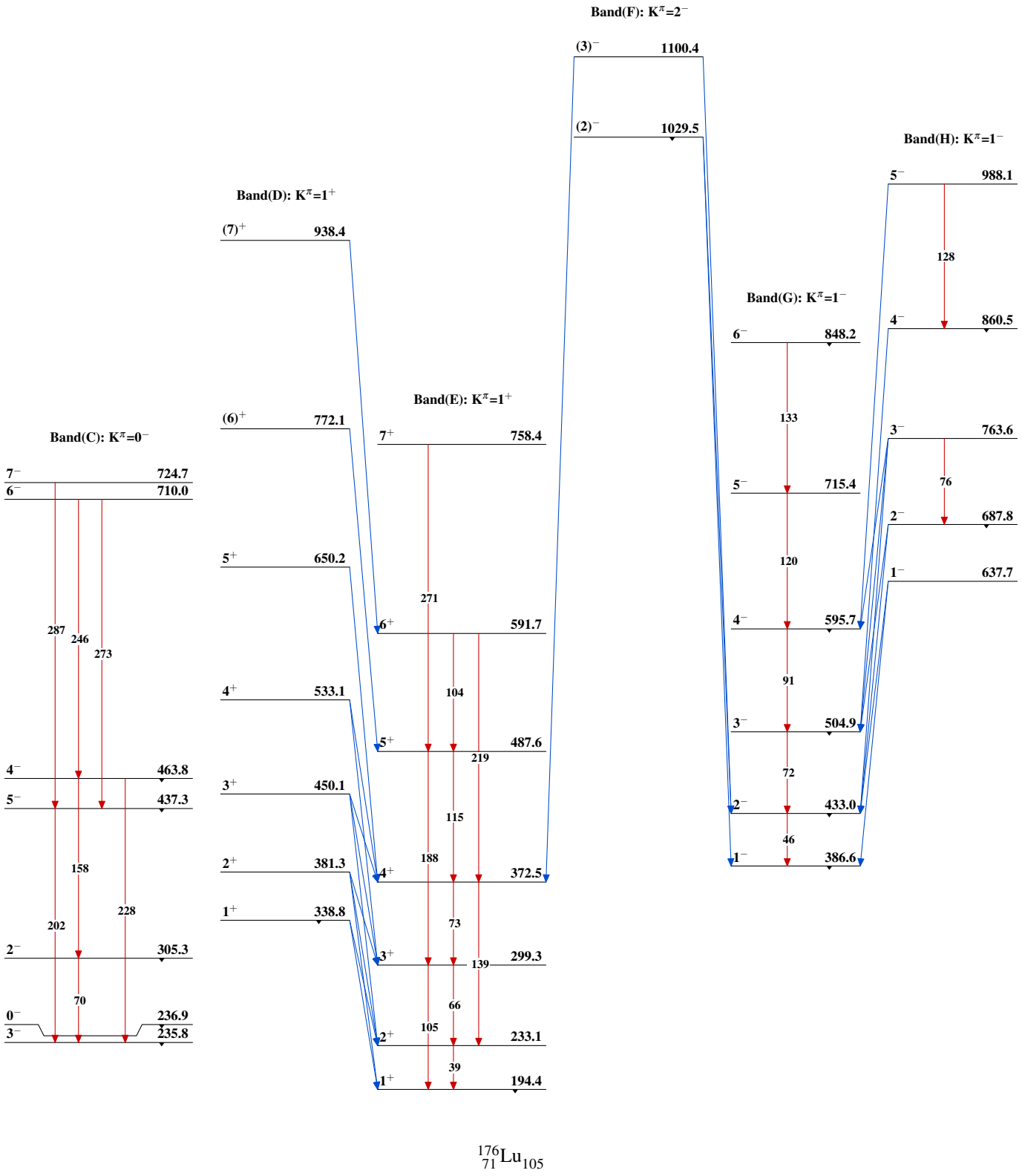
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28



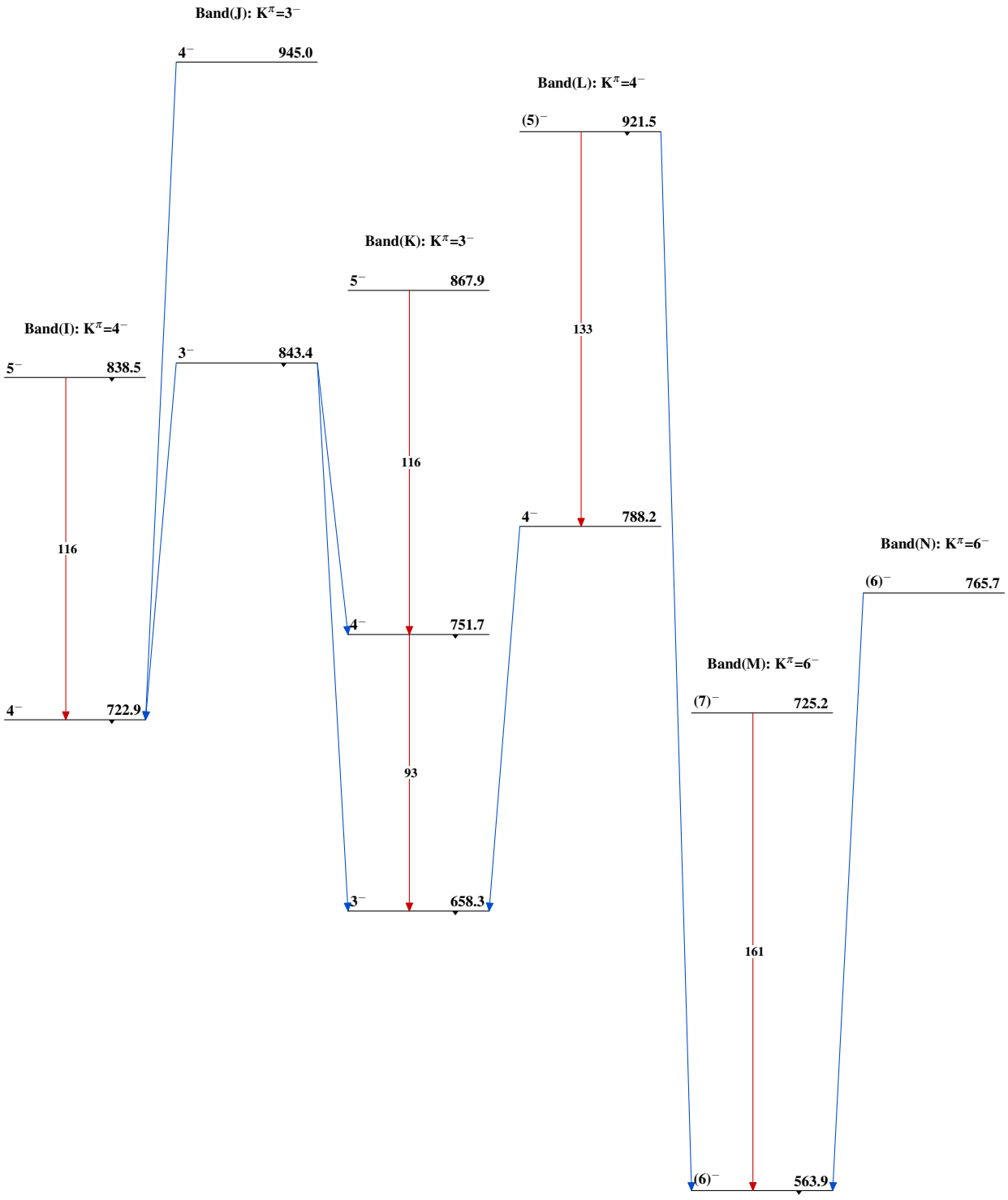
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28 (continued)



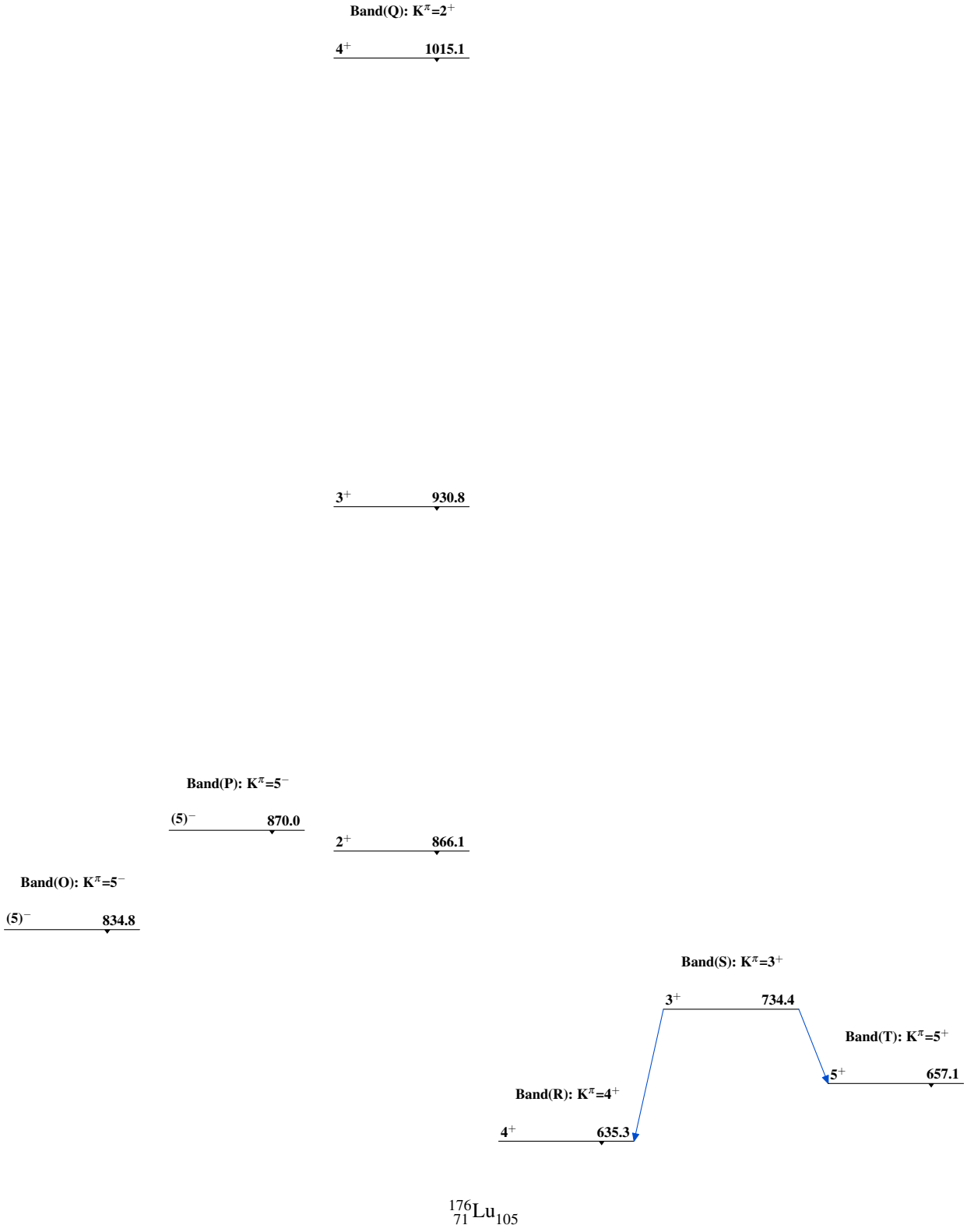
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28 (continued)



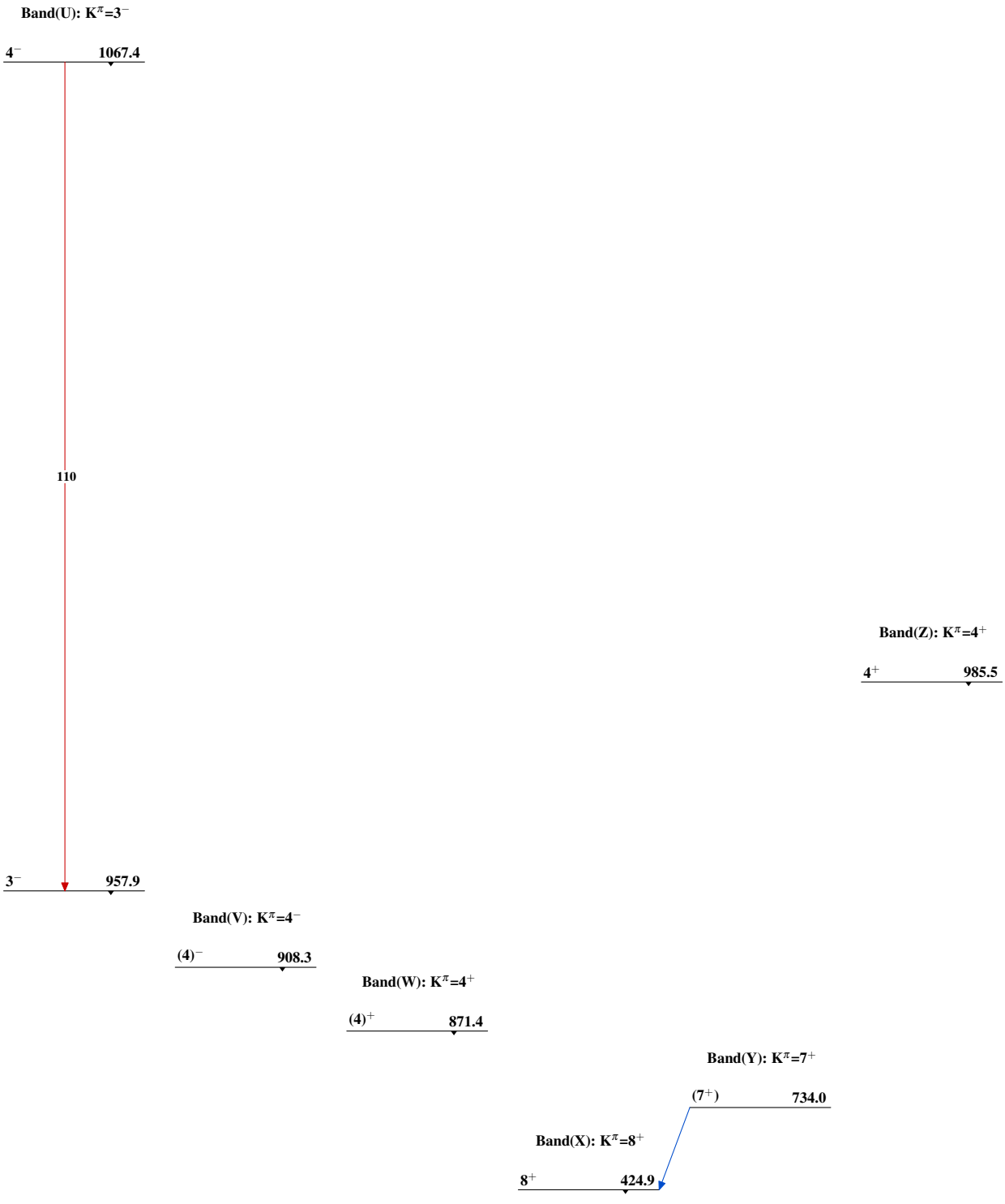
$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28 (continued)



$^{176}_{71}Lu_{105}$

^{176}Yb(p,nγ) 1991Le28 (continued)



$^{176}_{71}Lu_{105}$